



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : B29C 70/20	A1	(11) International Publication Number: WO 00/37244 (43) International Publication Date: 29 June 2000 (29.06.00)
--	-----------	---

(21) International Application Number: PCT/GB99/04293

(22) International Filing Date: 17 December 1999 (17.12.99)

(30) Priority Data:
9828368.2 22 December 1998 (22.12.98) GB

(71) Applicant (for all designated States except US): BRITISH AEROSPACE PUBLIC LIMITED COMPANY [GB/GB]; Warwick House, P.O. Box 87, Farnborough Aerospace Centre, Farnborough, Hampshire GU14 6YU (GB).

(72) Inventor; and

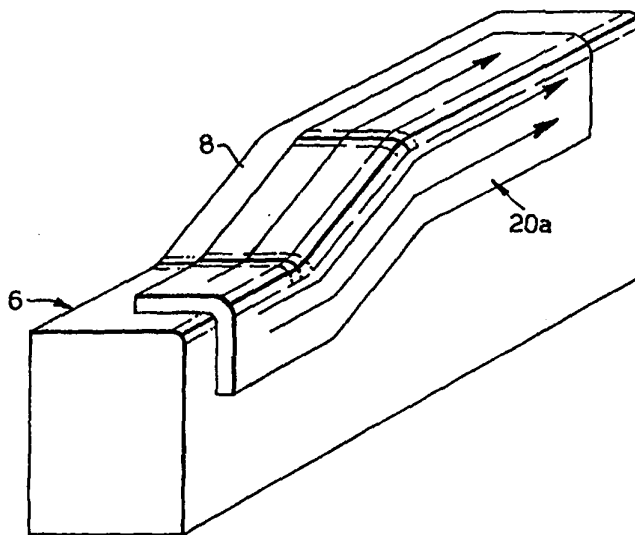
(75) Inventor/Applicant (for US only): WILLIAMS, Stephen [GB/GB]; British Aerospace Airbus, New Filton House, Filton, Bristol, Avon BS99 7AR (GB).

(74) Agents: EDIS, Ronald, Malcolm et al.; British Aerospace Plc, Group IP Dept. Farnborough Aerospace Centre, Lancaster House, P.O. Box 87, Farnborough, Hampshire GU14 6YU (GB).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published*With international search report.**Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

(54) Title: FORMING REINFORCING COMPONENTS



(57) Abstract

A method of forming a substantially planar, multi-layer, composite article that comprises a plastics materials reinforced with fibres that extend substantially continuously in one direction in the plane of each layer is provided. The majority of the layers are aligned in a main direction B and the article (20a) is disposed over a contoured surface of a forming tool (6). The article (20a) is constrained against movement in a direction perpendicular to the plane of the main direction layers and forces applied to the article (20a) in the plane thereof in a direction substantially perpendicular to the main direction of the fibres. The article (20a) is thereby urged into conformity with the contoured surface of the tool (6) whilst substantially maintaining the continuity of the fibres.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece	ML	Mali	TR	Turkey
BG	Bulgaria	HU	Hungary	MN	Mongolia	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MR	Mauritania	UA	Ukraine
BR	Brazil	IL	Israel	MW	Malawi	UG	Uganda
BY	Belarus	IS	Iceland	MX	Mexico	US	United States of America
CA	Canada	IT	Italy	NE	Niger	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NL	Netherlands	VN	Viet Nam
CG	Congo	KE	Kenya	NO	Norway	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NZ	New Zealand	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	PL	Poland		
CM	Cameroon	KR	Republic of Korea	PT	Portugal		
CN	China	KZ	Kazakhstan	RO	Romania		
CU	Cuba	LC	Saint Lucia	RU	Russian Federation		
CZ	Czech Republic	LI	Liechtenstein	SD	Sudan		
DE	Germany	LK	Sri Lanka	SE	Sweden		
DK	Denmark	LR	Liberia	SG	Singapore		
EE	Estonia						

FORMING REINFORCING COMPONENTS

This invention relates to forming reinforcing
5 components, and in particular to forming a composite fibre
reinforced plastics article to conform with a contoured
surface.

Articles formed in accordance with the present
invention have a variety of applications, but by way of
10 example only, and without limitation to the generality,
reference will be made to the forming of reinforcing
components used in the aircraft industry, for example
aircraft stringer sections.

When forming such components, in order to maximise
15 their structural effect, it is desirable to ensure that
the fibres of the component follow the contours thereof as
closely as possible. Such a component may be produced by
manually laminating a succession of prepreg plies so as to
form a multi-layered stack, but this is very time
20 consuming. "Prepreg" material consists of one or more
plies of Jibson's reinforcing material pre-impregnated
with uncured resin or like matrix material.

It is known to form a thick stack of uncured prepreg
material to provide reinforcement in one direction. As
25 can be seen from Figure 1 of the accompanying drawings, a
flat sheet 2 of uncured prepreg having a large plurality
of carbon fibres embedded in epoxy resin, with the fibres
aligned in the direction of the arrow A, has been formed
into a 90° bend over the edge of a forming tool 4. In
30 this way, an L-shaped stiffener is made, and it can be
envisaged that with a larger sheet of prepreg two bends
could be made so as to provide a channel section, with the
fibres thereof extending undirectionally. Such a method

ponent, however, has the disadvantage that utilized when the surface to which the conform is contoured, for example a angle or a ramp, or being undulating. Such es introduce diversions into the path of h, instead of following the contour, flow radius (see figure 2), and are thus no aligned in the required load-bearing e reinforcing effect is thus not so

ly, cutting a shaped blank such that it conformity to the underlying contoured in load bearing fibres being cut. Figure anying drawings shows a forming tool 6 that n of the tool 4 of Figure 1, in that its provided with a ramp 8. Figure 3 shows a k 10 that has been subjected to two cuts 12 and 14 so as to achieve the conformity, he 90° bend but also along the ramp 8 of

object of the present invention to provide ing method.

ence with one aspect of the present is provided a method of forming a anar, multi-layer, composite article that stics material reinforced with fibres that ally continuously in one direction in the yer, wherein a majority of the layers are main direction, wherein the article is a contoured surface of a forming tool, cle is constrained against movement in a ntially perpendicular to the plane of said layers , wherein force is applied to the

article in the plane thereof in a direction substantially perpendicular to the said main direction of said fibres, thereby to urge the article into conformity with the contoured surface of the tool whilst substantially
5 maintaining the continuity of the said fibres.

Depending on the viscosity of the resin of the composite article, heat may need to be applied thereto in order to ensure that the layers, or laminates, are able to slide with respect to each other.

10 Typically, although the fibres within each layer will be substantially unidirectionally aligned, not all the layers will be aligned. The actual alignment of the plurality of layers will depend on the structural load requirements, of tension and torsion for example. Normally a majority of
15 the fibres, and of the layers are aligned in one main direction for reinforcement, referred to as the 0° direction. Various other layers may then be aligned at 45°, 190°, and 135° thereto as required. For example, 50% of the layers/fibres may be in the 0° main direction, with
20 20% each at 45° and 135°, and 10% at 90°.

The invention thus results in a composite article that is contoured, for example to conform with the shaping of a joggle or ramp, without any of the fibres in the said load-bearing direction being cut. The contouring has been
25 effected by applying a force to the planar article whilst simultaneously preventing any buckling thereof.

Preferably, the article is constrained by being loaded into a support that allows flexibility in a direction to achieve the required contouring but which is
30 rigid in a direction perpendicular thereto. Advantageously, the support may comprise an elastomeric

material reinforced with spaced apart rigid rods, of aluminium or steel for example.

The support is preferably mounted in a rigid frame that is located around the forming tool and that is
5 arranged to guide the article in a direction towards the contoured surface during the forming process.

The force may be provided by a press acting on an edge of the planar article. Alternatively, the article, tool, frame and support may be located in an enclosure
10 that is then evacuated.

The contoured, planar reinforcing article thus produced, may be subjected to a further forming operation in which heat is again applied thereto and a force is applied to effect further forming thereof. For example
15 the further forming operation may be arranged to produce a fold about a line in the planar surface of the article, the line preferably extending substantially parallel to the direction of the said fibres, thus producing an L-shaped article. A further forming operation may be
20 arranged to produce a channel-shaped article, or one of any desired shape.

Thus, the present invention provides a method of forming a substantially planar, multi-layer composite article such that it is able to conform to a substrate
25 that comprises three contiguous surfaces each of which is angled, i.e. lies at other than 0° , to the other two surfaces. The surfaces may be generally planar, but may for example, be convoluted and may comprise a ramp or a joggle.

30 The plastics material of the article may be thermoplastics. Alternatively, the plastics material may be curable, for example being a thermoset, with curing being effected after the forming thereof has been completed.

The reinforcing fibres may be of carbon, aramid or glass, for example.

It is to be understood that although reference has been made to directions with respect to the orientation of
5 continuous fibres in the plane of the article, the composite article may include fibres in layers at various other angles to this primary load-bearing direction.

The method of the present invention finds particular application to a multi-layer composite article, due to its
10 increased rigidity with respect to a relatively flexible single ply article. Thus, the article to which the present invention is particularly beneficial is envisaged as comprising at least two plies, each of which would typically be between 0.125 and 0.25 mm thick, and
15 typically would have a minimum of 8 plies, thus giving a thickness of 2 to 3 mm, and may even be formed as a 5 mm thick stack of 20 plies, or more. It will be appreciated that the number of plies, and thus the thickness of the article would depend on the loading to which it was to be
20 subject in use.

In accordance with a further aspect of the present invention, there is provided apparatus for forming a substantially planar, multi-layer composite article, comprising means for constraining the article in a
25 direction substantially perpendicular to its plane, means for mounting the article over a contoured surface to which it is to be conformed, and means for applying a force in a direction in the plane of the article to urge the article into conformity with the contoured surface.

30 The apparatus is preferably arranged to carry out the features of the method of the invention.

A method of forming a multi-layer, composite article, in accordance with the present invention, will now be

described, by way of example, with reference to Figures 4 to 9 of the accompanying drawings, in which:

Figure 4 is a partially cut-away perspective view of a flexible support with a preform blank of the article 5 partially inserted thereinto;

Figure 5 is a view of one end of the support of Figure 4 prior to its closure;

Figure 6 is an end view of the supported article of Figure 4 retained within a rigid frame, mounted on a 10 forming tool and enclosed within a vacuum bag;

Figure 7 is a perspective view corresponding to Figure 6;

Figure 8 is a plan view of the preform subsequent to a first forming operation; and

15 Figure 9 is a perspective view of the finished article on a forming tool after undergoing a further forming operation.

Referring to Figures 4 and 5, a multi-layer preform blank 20 comprises a rectangular planar body of epoxy 20 resin containing carbon fibres in which a majority of the layers and fibres extend along the direction B continuously from one end to the other thereof. The blank 20 is shown being introduced into a flexible support 22 that is formed of rubber and has stainless steel 25 stiffening rods 27 embedded therein. The support 22 is in two parts, comprising a three-sided channel section 24 and a removable cover 26, each of which has correspondingly-shaped rods 27 embedded therein. Additionally, as can be seen in Figure 5, the cover 26 has, at each end thereof, a 30 protrusion 28 that is arranged to clamp the blank 20 at its ends when it is loaded completely into the channel section 24 of the support 22.

Referring to Figures 6 and 7, the preform blank 20, mounted in the flexible support 22 is clamped along its length and over an intermediate portion only of its height between two rigid aluminium frame members 30. The frame members 30 position the supported blank 20 over the upper contoured surface of the form tool 6. The frames 30 act together with the stiffeners 27 of the support 22 to prevent any substantial deformation of the blank 20 in a direction perpendicular to the vertical plane thereof, whilst allowing the reinforced support 22 containing the blank 20 to be guided in the vertical plane. The blank 20, support 22 and frames 30, are enclosed within a vacuum bag 32 (Figure 6).

In operation, the air within the bag 32 is pumped out, thereby exerting a vertically-downward load on the exposed upper portion of the blank 20 within the support 22. At the same time, heat is applied to soften the curable material of the blank 20, the exposed lower portion of which consequently, and together with the support 22, is forced into conformity with the upper ramped contour of the form tool 6. The vacuum is maintained within the bag 32 whilst the blank 20 is allowed to cool and thus to solidify into its conformed shape. The resultant planar component 20a, after removal from the deformed support 22, is shown in Figure 8. As can be seen from Figure 8, the component 20a is shaped to configure to the ramp 8 with the unidirectional fibres extending continuously in the direction B.

Figure 9 shows a further forming step that may be carried out on the component 20a, whereby its planar surface is formed into a right angle, whilst still conforming to the ramp 8 of the form tool 6. This operation is carried out whilst applying increased heating

to the component 20a, whilst still subject to a vacuum or other deforming force, whereby it is softened to allow the 90° angle to be formed therein, and is subjected to such a temperature that the epoxy material thereof is cured.
5 Alternatively, curing may be carried out during a subsequent operation, for example when the main skin component, with which the article is associated, is itself cured.

The resulting article thus extends in three planes
10 that are angled to each other, and the continuity of the uni-directional, load-bearing fibres is maintained.

It will be appreciated that by suitable choice of the form tool, the initial preform blank can be formed into any required configuration so as during the initial
15 forming step to conform to a ramp, joggle or other disturbance from a plane, whilst maintaining continuity of the fibres in the required load-bearing direction. Further forming may then take place to provide, for example, an L or C-shaped sectioned member. The resulting
20 component can then be removed from the form tool and applied as reinforcement to the required structural member, for example an aircraft stringer section.

Claims

1. A method of forming a substantially planar, multi-
5 layer, composite article that comprises a plastics
material reinforced with fibres that extend substantially
continuously in one direction in the plane of each layer,
wherein a majority of the layers are aligned in a main
direction, wherein the article is disposed over a
10 contoured surface of a forming tool, wherein the article
is constrained against movement in a direction
substantially perpendicular to the plane of said main
direction layers, wherein force is applied to the article
in the plane thereof in a direction substantially
15 perpendicular to the said main direction of said fibres,
thereby to urge the article into conformity with the
contoured surface of the tool whilst substantially
maintaining the continuity of the said fibres.
- 20 2. A method according to claim 1, wherein the
constraining of the article is carried out by mounting the
article in a flexible support that is reinforced in, or
parallel to, the plane of said main direction of the
article.
- 25 3. A method according to claim 2, wherein the support
comprises an elastomeric material reinforced with spaced-
apart rigid rods.
- 30 4. A method according to claim 2 or 3, wherein the
support is in the form of a container that receives the
planar article.

5. A method according to any one of claims 2 to 4, wherein the reinforcement is arranged substantially to prevent movement of the article in the said main direction of the said fibres.

5

6. A method according to any one of claims 2 to 5 wherein the support is mounted in a rigid frame located around the forming tool and is arranged to guide the article in a direction towards the contoured surface of
10 the forming tool under the action of the said force.

7. A method according to any one of the preceding claims, wherein the force acting on the article is produced by means of a press or a vacuum.

15

8. A method according to any one of the preceding claims, wherein subsequent to the said conforming operation, a further forming operation is carried out whereby the article is heated and force is applied thereto
20 such that it is folded about a line in its planar surface that extends substantially parallel to the said main direction of the said fibres.

9. A method according to any one of the preceding
25 claims, wherein the plastics material of the article is curable and is cured after the forming thereof has been completed.

10. A method according to claim 9 when dependent on claim
30 8, wherein the plastics material comprises a thermoset, and wherein sufficient heat is applied only during the further forming operation to effect curing thereof.

11. A method according to any one of the preceding claims, wherein the article comprises a carbon- or glass-fibre reinforced plastics material, and is formed as a structural reinforcing member with the said fibres in the main direction aligned in the main load-bearing direction thereof.
12. A method according to any one of the preceding claims, wherein the contouring of the forming tool is arranged to allow the formed article to conform to a joggle or a ramp.
13. A method according to any one of the preceding claims, wherein the article is softened by the application of heat prior to applying said force thereto.

1/3

Fig.1.

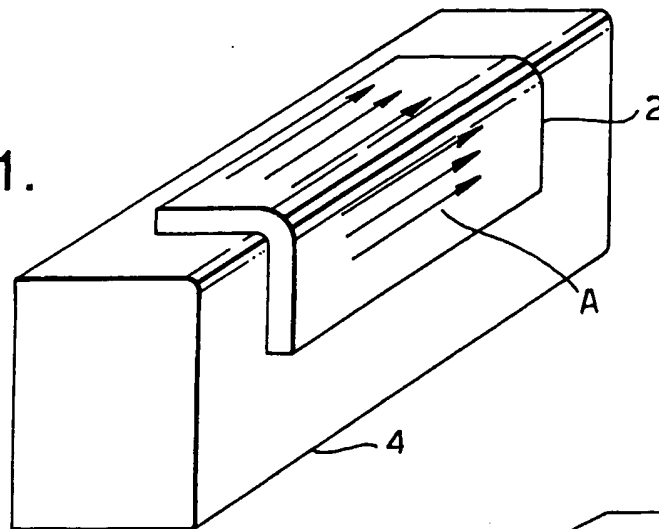


Fig.2.

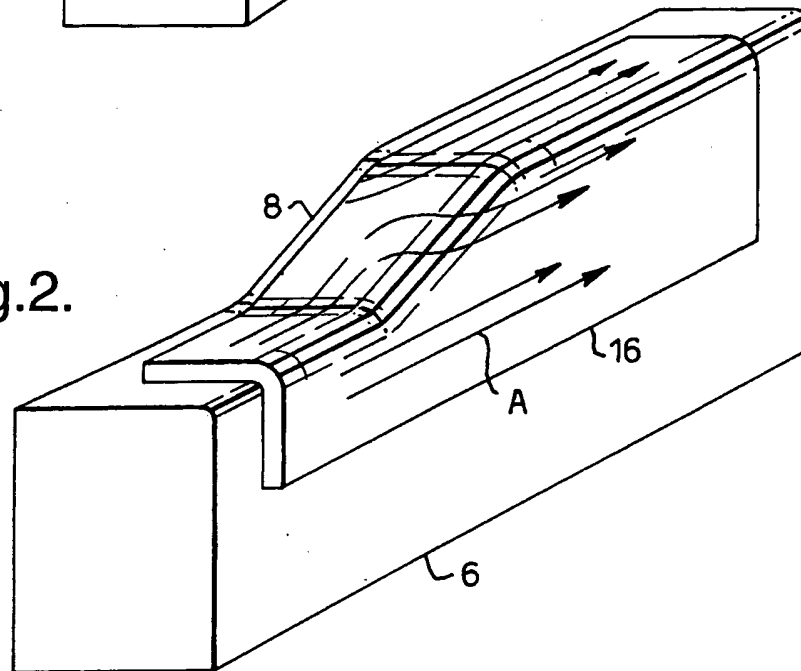
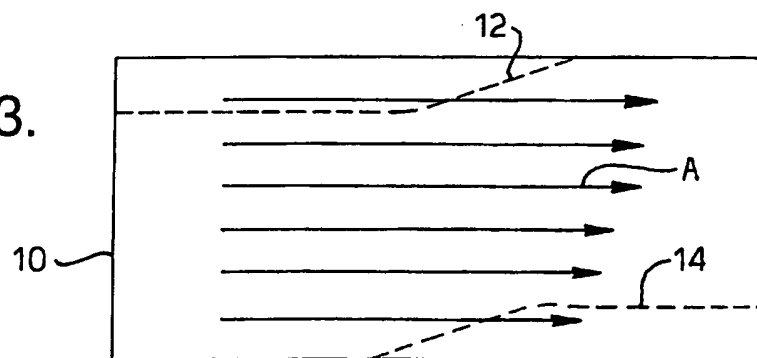


Fig.3.



2/3

Fig.4.

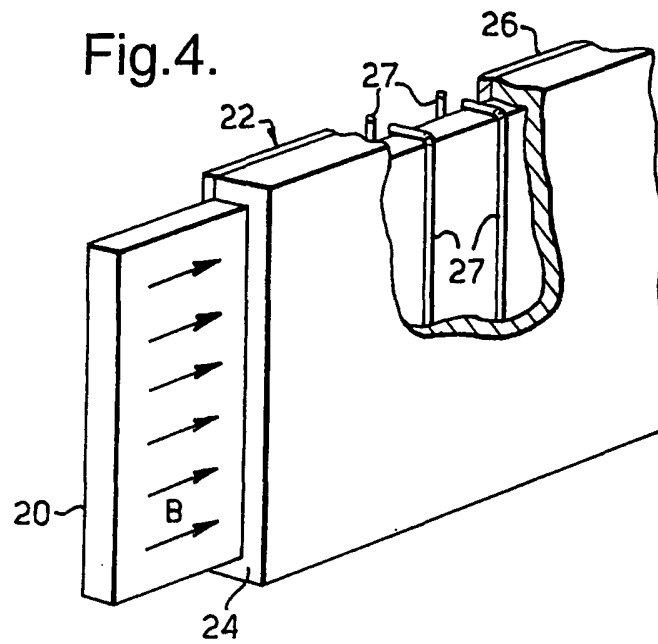


Fig.5.

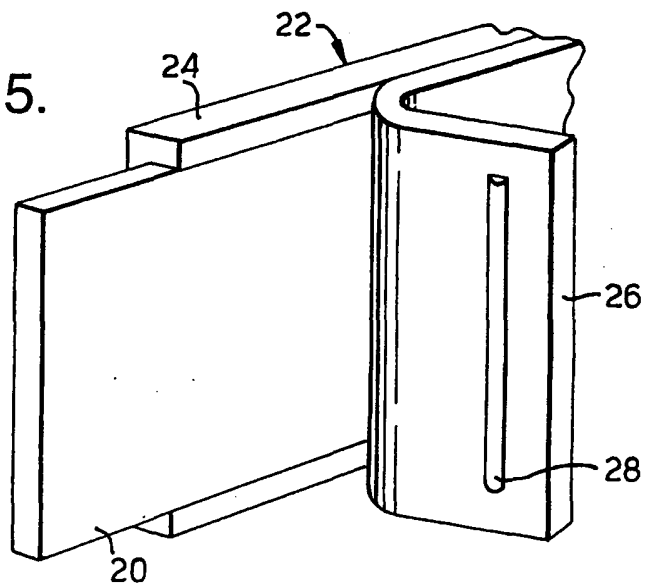
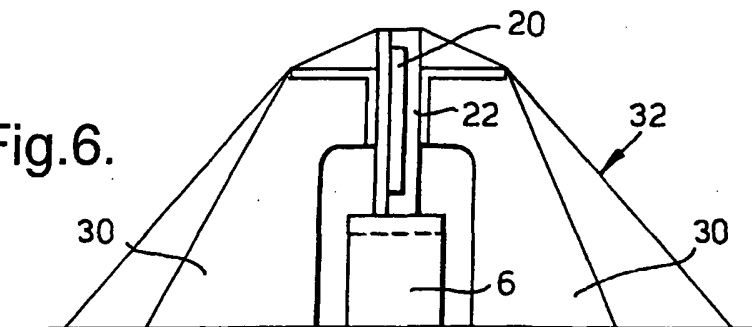
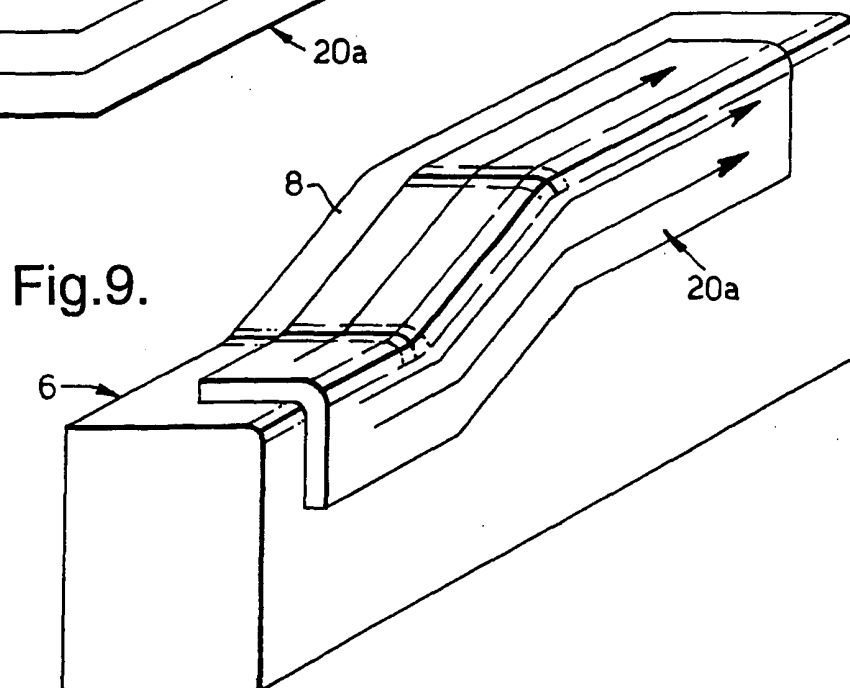
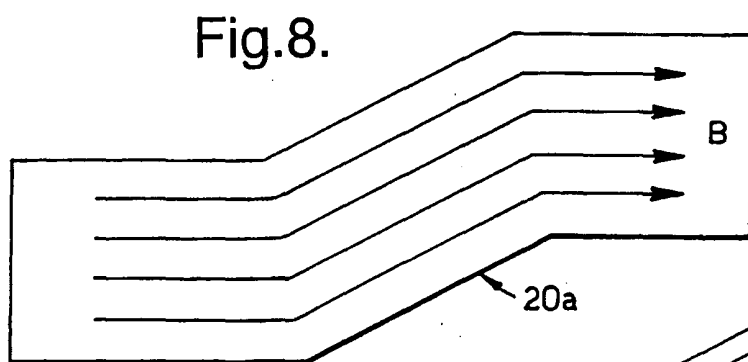
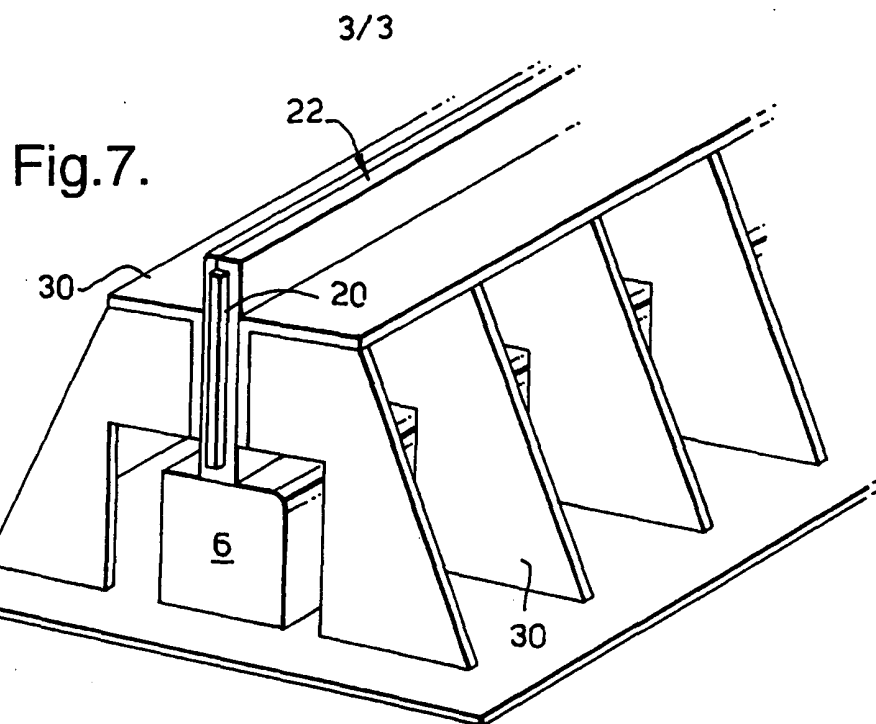


Fig.6.



SUBSTITUTE SHEET (RULE 26)



INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 99/04293

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B29C70/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 B29C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GUTOWSKI T ET AL: "DIFFERENTIAL GEOMETRY AND THE FORMING OF ALIGNED FIBRE COMPOSITES" COMPOSITES MANUFACTURING, GB, BUTTERWORTH SCIENTIFIC, GUILDFORD, SURREY, vol. 2, no. 3 / 04, 1 January 1991 (1991-01-01), pages 147-152, XP000274494 ISSN: 0956-7143 page 150, column 2 -page 152, column 2 ---	1,7, 9-11,13
X	US H1162 H (YAMAMOTO ET AL.) 6 April 1993 (1993-04-06) claims; figures -----	1,7, 9-11,13

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"G" document member of the same patent family

Date of the actual completion of the international search

28 April 2000

Date of mailing of the international search report

08/05/2000

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Van Wallene, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/04293

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US H1162	H	06-04-1993	JP 5023568 B	05-04-1993
			JP 63212517 A	05-09-1988
			JP 1865164 C	26-08-1994
			JP 63183836 A	29-07-1988
<hr/>				